THE GLENORMISTON METEORITE.

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(Plates III–VIII.)

INTRODUCTION.

In 1925 a metallic substance was forwarded by Mr. George Wood, Clerk of Boulia Shire Council, to myself as Professor of Geology in the University of Queensland, as a result of which its meteoric character was recognised. Following upon this, about a year later, the Queensland Museum purchased the meteorite from Mr. F. H. Story, late manager of Glenormiston Station where it was found.

The mass received by the Queensland Museum shows evidence of one or two small pieces having been forced away, but it is in a reasonably complete condition, and as the list of Queensland meteorites is small some interest is attached to its description.

The main specimen on being received weighed 85½ lb., and in shape was an irregular sub-triangular shell-like mass with distinct concave and convex surfaces.

The small specimen originally forwarded to myself for examination weighed approximately 750 grammes, while another one forwarded to Mr. B. Dunstan, Chief Government Geologist, weighed approximately the same amount.

The chemical analysis made in the Government Chemical Laboratory by Mr. F. Connah through the courtesy of Mr. J. B. Henderson, Government Analyst, was made on borings from the specimen forwarded to myself.

A fragment weighing 1,550 grammes has been sawn from the main mass to afford a surface for etching purposes and for examination; the line of parting is shown on Plate III.

OBSERVATIONS ON QUEENSLAND METEORITES.

In the Records of the Australian Museum, Sydney, 1913, Dr. C. Anderson furnishes a Catalogue of Australian Meteorites and gives six Queensland meteorites, of which four are of the siderite type and two are aerolites (the Legould and the Warbreccan).

The siderites are Mungindi No. 1 and No. 2 (portions of the same fall), a meteorite from Southern Queensland referred to in the Catalogue of Ward and Coonley Collection of Meteorites 1904, and the Thunda meteorite.

The only other Queensland meteorites apart from the Glenormiston one known to the author are an undescribed siderite (coarsest octahedrite) weighing $14\frac{1}{2}$ cwt., found near Gladstone and disposed of by Mr. B. Dunstan to Ward's Natural History Establishment, New York, and an undescribed collection of 102 fragments of various sizes and aerolitic in character which were seen to fall on Tenham Station near the junction of Cooper and Kyabra Creeks, in South-western Queensland, in the year 1869, by Mr. M. Hammond and his brothers.

The Mungindi No. 1 and No. 2 weigh 51 lb. and 62 lb. respectively, are finest octahedrite (off., Brezina) or fine octahedrite (of., Farrington), and were found in 1907 three miles north of Mungindi, which is on the border of Queensland and New South Wales in Lat. 29° S., Long. 149° E. The specimens are now in the Mining and Geological Museum, Sydney.

The meteorite recorded in the Ward and Coonley Collection is a broad octahedrite (og.) and came from Southern Queensland.* As the only meteorite of this type known in Queensland is the Gladstone meteorite, and as a part of this has been missing for many years, it is possible that this represents the missing portion.

The Thunda siderite weighed 137 lb., is a medium octahedrite (om.), and was found in 1886 at Windorah in the Diamantina district, Lat. 25° 25′ S., Long. 142° 40′ E., some 300 miles south-east of Glenormiston. It was described by the late Professor A. Liversidge, F.R.S. (Proc. Roy. Soc. N.S.W., vol. 20, p. 73, also vol. 22, p. 341).

Its density is given as 7·78 and its composition as nickel iron containing a trace of cobalt together with sulphur, phosphorus, and carbon. "The pittings are very large and cup-like and some of them almost perforate the meteorite" (Proc. Roy. Soc. N.S.W., xxii, p. 341).

"This meteorite is also remarkable for the many nodules of sulphide of iron which it contains" (A.A.A.S., vol. ii. 1890, p. 387).

In Bull. 94 U.S. Nat. Museum the analysis by E. Cohen of this meteorite is given, and from it Cohen calculated the mineral composition to be as follows :—

	Per cent.
Nickel iron	98·85
Schreibersite	1·09
Troilite	0·05
Chromite	0·01

The following particulars relating to the Gladstone meteorite, which was purchased by Ward's Natural History Establishment, New York, some time ago, have been kindly furnished by Mr. B. Dunstan, Chief Government Geologist. :—

It was found in 1914 four miles due south of Gladstone, two and a-half miles north-west from Tooloola Siding, was approximately 33 inches by 12 inches by 9 inches (mean dimensions), has a density of 7·75, and weighs $14\frac{1}{2}$ cwt.

An analysis by Mr. F. Connah of the Government Analyst's Laboratory "of chips from all over specimen of iron portion" is shown in the table of analyses in this paper.

Large nodules of troilite, of which one was 1 inch by $2\frac{1}{2}$ inches in section, occurred and "apparently there is a mixture of coarse troilite (crystals), graphite, and particles of iron in the nodules." Analysis of a nodule yielded :—

	Per cent.
Iron	59·4
Nickel	2·0
Cobalt	0·3
Sulphur	33·4
Residue	2·3
Total	97·4

The polished section (*see* Plate VIII) after etching with dilute nitric acid exhibited very good Widmanstätten figures ; the lamellæ are very coarse and range up to 4 mm. in width, the large majority being greater than 2·5 mm.

It comes within the coarsest octahedrite classification of Farrington or octahedrite (ogg., Brezina).

The curious and interesting obsidian buttons or australites which have been found in other Australian States have not yet been recorded definitely from Queensland. Some years ago Mrs. Saunders, the widow of a man interested in tin-mining in Northern Queensland, presented the University Geological Department with a collection of minerals, and in a tobacco tin containing pellets of cassiterite were two small undoubted australites which had been worn and knocked about to some extent. They weighed 1·005 and 0·591 grammes respectively and have densities as follows : 2·436 and 2·581.

Whether they really came from tin-wash in Northern Queensland we will probably never be able to settle, but it is interesting to know that Mrs. Saunders did not know of their existence in the sample of cassiterite pellets.

THE GLENORMISTON METEORITE.

Time and Place of Falling.

The date of falling is unknown, and the only available information relating to the finding is contained in a letter from Mr. F. H. Story, dated November 14th, 1926 :

". . . I regret that I cannot give you much information regarding it, as no one knew when or saw it fall. It was discovered when one of the boys was tracking a stray horse, who brought me home a small piece. I then sent the car and got the balance of it in. It fell on a small plain about 5 miles west of Glenormiston Station House in the Boulia district or to be exact 90 miles west of Boulia." This would make its location about Lat. 22° 54′ S., Long. 138° 43′ E.

Size and Weight.

The size on receipt at the Museum was $19\frac{1}{2}'' \times 13\frac{1}{5}'' \times 8\frac{3}{4}''$ and its weight was $85\frac{1}{2}$ lb. As indicated earlier, at least two fragments weighing together a few pounds are known to have been removed, so that the meteorite weighed at least 90 lb.

Form.

The meteorite, owing to having distinct concave and convex surfaces with a maximum thickness between them of not more than 4 inches, may best be regarded as a deeply pitted shell-like fragment, which has a maximum length of 19·5 inches and a maximum width of 13·2 inches. When resting on its convex surface (*see* Plate V) the highest point above the table is 8·8 inches.

Both surfaces have been coated with a thin film of dark chocolate brown iron oxide crust, and only where the original surface has been broken is there any indication of the distinctly brecciated character of the meteorite.

Both surfaces are well pitted, but the concave surface has several cup-like depressions as much as 5 inches in depth in one case. The depressions are relatively smooth and run one into the other, also they may be roughly ovate or circular in form The deepest depression perforates the mass. The convex side is more characteristically "thumb-marked," an average width for the shallow rounded depressions being $1\frac{1}{2}$ to 2 inches, while the perforation from the deep depression on the concave surface shows up as a rounded hole approximately an inch in diameter.

The shell has a maximum thickness of 4 inches, but over much of its area is rather less, perhaps 2 inches on the average.

Brecciated Character.

The very thin crust of iron oxide disguises rather effectively the distinctly brecciated character of the mass. The individual granules of kamacite, which in cross-section are polygonal (five or six sides being the usual number) and which are generally equidimensional in size, vary in diameter from 13 mm. to 2·5 mm., but have an average diameter of approximately 6 mm.

In between the kamacite granules plate-like crystals of tænite and probably plessite are arranged eutectically, while distributed through the kamacite crystals themselves are troilite granules and rounded to irregular granules of what is believed to be schreibersite (*see* Plates VI and VII).

Chemical Composition.

The following chemical analysis was made by Mr. F. Connah, of the Government Analyst's Laboratory, on the borings made by drilling a half-inch hole to a depth of $1\frac{1}{2}$ inches.

For comparison, the analysis has been arranged in a table along with the average composition of iron meteorites as determined by Merrill,[1] with the

[1] Proc. Amer. Phil. Soc., xlv, 1926, p. 124.

analysis of the Thunda meteorite of Queensland and with the analyses of iron meteorites from Gladstone in Queensland, from Mount Edith in Western Australia, from South Australia, from Narraburra in New South Wales, and from Cranbourne in Victoria.

The general description by Professor Liversidge of the Thunda meteorite corresponds closely with that of the Glenormiston meteorite, and as the chemical analyses are so similar it is not at all unlikely that they constitute portions of the same original mass, although found approximately 300 miles apart.

—	The Glenormiston Meteorite, Qld.	Average [2] Composition of Meteorites	Iron Nickel portion of Gladstone Meteorite, Qld.	Thunda [3] Meteorite, Qld.	Narraburra [4] Meteorite, N.S.W.	Cranbourne [5] No. 2 Meteorite, Vic.	Meteorite, [6] S.A.	Mt. Edith [7] Meteorite, W.A.
Iron	89·74	90·85	92·9	91·54	88·605	92·34	88·85	89·45
Nickel ..	8·71	8·52	6·4	8·49	9·741	6·3 [illegible]	9·07	9·45
Cobalt ..	0·21	0·59	0·1	0·56	0·474	0·75	0·34	0·75
Phosphorus ..	0·36	0·17	0·18	0·17	0·429	0·19	0·27	0·35
Sulphur ..	0·30	0·04	Nil	0·02	traces	0·18	0·75	
Carbon ..	0·24	0·03	Nil	..	0·008			
Copper ..	..	..	..	0·02				
Chromite ..	..	..	..	0·01				
Difference ..	0·44							
Total ..	100·00	..	..	100·81	..	..	..	100·00
Density ..	7·621	..	..	..	7·57	..	7·693	
Fe : Ni ..	10·3 : 1	10·7 : 1	14·5 : 1	10·8 : 1	9·1 1	14·5 : 1	9·8 : 1	9·5 : 1
Weight ..	85½ lb	..	..	137 lb.	71 lb.	3[illegible] cwt.	7½ lb.	350 lb.
Analyst ..	F. Connah	..	F. Connah	..	..	..	W. S. Chapman	
Classification	Brecciated medium octahedrite (obz.)	..	Coarsest octahedrite	Medium octahedrite (om.)	..	Broad octahedrite	Octahedrite	Medium octahedrite (om.)

The chemical analysis shows nothing abnormal or unusual in any way, and is closely comparable with that of several iron meteorites from Australia and elsewhere.

In comparison with the average composition of iron meteorites it appears to be a little deficient in cobalt but mueh richer in phosphorus, sulphur, and carbon. Such a comparison, however, may be deceptive as it is not likely that there is a linear variation of the constituents of iron meteorites, and comparison with an average composition may be very misleading.

[2] Proc. Amer. Phil. Soc., xlv, p. 124.

[3] Bull. 94, U.S. Nat. Mus., p. 158.

[4] Proc. Roy. Soc. N.S.W., xxxvii.

[5] Mem. Nat. Mus. Melb. No. 6, p. 22.

[6] Proc. Roy. Soc. S. Aust. 1901, p. 14.

[7] Bull. 59, Geol. Surv. West Aust., p. 212.

The relationship between the structure as revealed by etching polished surfaces and the percentage of nickel has been well established by O. C. Farrington and adopted by G. P. Prior[8] and others.

The cubic irons or hexahedrites have an iron to nickel ratio greater than 13 : 1, while the octahedral irons or octahedrites which constitute the main bulk of the meteoric irons range between 13 : 1 and 6 : 1.

The Glenormiston iron with its ratio of 10·3 : 1 is, therefore, in the group of octahedrites on this basis, and one might expect it to show the minerals and structures characteristic of that placing. On etching a polished surface, however, one does not obtain the Widmanstätten structure so characteristic of the octahedrites, but instead there is developed the structures shown in the cubic irons or hexahedrites. The fact that the meteorite is so definitely brecciated may account for this.

On the iron-nickel ratio the Glenormiston meteorite is a medium octahedrite.

Examination of the figures in Plate VI will show the uneven distribution of the troilite, schreibersite, and the tænite throughout the main mass of kamacite crystals, and the borings analysed may perhaps be not truly representative of the mass as a whole. The correct sampling for analysis of a brecciated iron meteorite of this type is a very difficult matter unless an undue quantity of material is dissolved.

Examination of Polished and Etched Surfaces.

Structures and Minerals present.

The meteorite is distinctly tough and the extreme labour and slowness associated with even quite small cuts with a hacksaw pointed to a rather high carbon content in the material. By means of a carborundum saw a face $5\frac{1}{2}$ inches long and 3 inches wide was obtained and subsequently polished. This was cut from one end of the meteorite as shown in Plate III.

The polished surface showed clearly the brecciated character and angular eutectic intergrowths of tænite and plessite could be seen in reflected light, while small nodules of troilite and larger nodular masses of schreibersite alone or mixtures of schreibersite and troilite could be detected by the use of reflected light without magnification and without artificial aid (*see* Plate VI).

The surface responded very readily to attack by dilute nitric acid ; the troilite nodules became dissolved leaving small rounded pits. The crystals of kamacite showed very well indeed the Neumann lines, while the angular platy intergrowths of tænite (and plessite) stood out in relief from the surface of the kamacite as it dissolved away. A beautiful damascene effect on some of the kamacite faces showed up in parts of the etched surface in the early stage of the attack and before the Neumann lines had been very well developed.

8 Miner. Mag., vol. xix.

When the etching was carried out still further the damascene effect became lost, the Neumann lines were well developed and the surface of the kamacite crystals became rough owing to the greater resistance of small pin-point portions which do not appear to an equal extent in all the kamacite surfaces, but which seem to have an even and rather systematic network distribution throughout the whole mass. These more resistant pin-points may indicate the existence of minute segregations of carbon throughoutt he kamacite.

The richer nickel-bearing material which has filled in the interstices between the kamacite crystals is very reminiscent of the form which quartz assumes in its intergrowth with felspar in graphic granite. These sharply angular and triangular masses have a distinctly yellowish reflecting surface compared with the kamacite, and not infrequently appear to have a marked border, rather thin but distinctly lamellar (*see* Plate VII, fig. 1). It may be that in these cases we may have an outer lamellar envelope of tænite wrapping up the plessite.

The troilite granules are all small, averaging little more than 1 mm. in diameter, though some reach 2 mm. They are abundant and distributed somewhat unevenly, occur indiscriminately in the kamacite, in the tænite and plessite, and sometimes form a compound granule with what is believed to be schreibersite.

This latter mineral occurs as irregular-shaped nodules, brittle in character, with a paler yellow reflecting surface than the troilite, with surfaces showing cleavage faces and much rougher than the nickel rich material filling the interstices, and offers considerable resistance to the attack of quite strong nitric acid.

Separate chemical analysis has not been carried out on this material, but it is believed to be schreibersite (iron-nickel phosphide).

The kamacite crystals are arranged, as one might expect in a brecciated octahedrite, with the Neumann lines of adjacent grains generally showing no relationship whatever to one another (Plate VII, fig. 2).

When the etched surface as a whole is viewed by reflected light, great variation is noted between adjacent crystals or adjacent groups of crystals in their surface illumination according to the incidence of the light. This so-called "schiller" effect of some writers on meteorites is very pronounced owing to the different orientation in different groups of plates, and is illustrated in the three figures of Plate VI, in which the same surface has been photographed with light coming from different directions. The curved line on the top surface of each figure marks the base of one of the cup-like depressions, and it is noteworthy that the fresh metallic material has only the thinnest oxidised coating. In the photographs on Plate VI the Neumann lines on the kamacite (*k*) plates are seen clearly. Schreibersite (*s*), tænite and plessite (*t*), and troilite (*tr*) may also be identified in the figures.

To Mr. H. A. Longman, Mr. B. Dunstan, Dr. F. W. Whitehouse, and Mr. A. N. Falk I wish to extend thanks for help in connection with the illustrations in this paper.

SUMMARY.

The Glenormiston meteorite, which weighed nearly 90 lb., may be regarded as a brecciated octahedrite of medium composition with a density 7·621.

It is composed essentially of crystals of kamacite averaging approximately 6 mm. in diameter and which are not orientated according to any definite arrangement as shown by their reflected surfaces, but which show well-developed Neumann lines after etching.

Tænite and plessite occur as eutectic intergrowths with the kamacite crystals, while troilite and schreibersite in the form of rounded or irregular nodules sometimes simple but often compound occur in moderate abundance.

Widmanstätten structure is not present.